Design Considerations for Replacing the 5G NR Physical Layer

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Acknowledgments.
Certain diagrams have been borrowed from the world’s first multimedia book on 5G:
About the Presenter…

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Expertise: 5G, O-RAN, NTN, LTE, IMS

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Presentation Goals

- Discover the motivation for replacing the 5G NR PHY layer
- Describe different strategies for replacing the NR PHY layer
- Summarize the impact of PHY changes on the 5G NR radio protocol stack
- Illustrate the impact of PHY layer changes on the 5G NR RAN
- Describe the impact of PHY layer changes on the 5GC
- Discuss the impact of PHY layer changes on the UE
01 Why Replace NR PHY?
02 NR Protocol Stack
03 NR Replacement Strategies
04 Impact of PHY Changes on RAN
05 Impact of PHY Changes on 5GC
06 Impact of PHY Changes on UE
01

Why Replace NR PHY?
The Power of 5G NR...

✓ New Radio (NR) is a flexible, efficient, and high-performance radio interface of 5G
Motivation for NR PHY Replacement

✓ Why rock the boat if 5G NR is so efficient, powerful, and flexible?

Easy for commercial users to detect signals and channels (e.g., SS/PBCH Block and PDCCHs) but adversaries can also easily attack!
NR Radio Protocol Stack

Q: What exactly are we replacing/changing in the 5G NR radio interface? The PHY layer does not exist by itself...it needs to work with other layers/protocols!

User Plane
- SDAP
- PDCP
- RLC
- MAC
- PHY

Control Plane
- RRC
- PDCP
- RLC
- MAC
- PHY

Layer 1
Layer 2
Layer 3

User Traffic (Layer 3)
NAS Signaling
Example Impact of PHY Changes on NR Protocol Stack

A million-dollar Q: What would happen if we change the NR PHY layer?

Red text: Requires significant changes due to a new PHY layer

Green text: No or minimal impact of a new PHY layer

However, different strategies can be used to accommodate a new PHY layer.

**RRC**
- System Information (Cell Selection, Random Access)
- Mobility signaling (Handover events, Measurements)

**PDCP**
- Reuse security (Ciphering & Integrity Protection) and RoHC

**MAC**
- Scheduling: Resource Allocation
- Awareness of the resource grid for the new PHY
- Reuse HARQ control (Code Block Groups (CBGs) may not be available in new PHY)

**RLC**
- Reuse Transparent Mode, Unacknowledged Mode (DRBs), and Acknowledged Mode
- Reuse ARQ (Acknowledged Mode)

**SDAP**
- Reuse QoS Flow <---> DRB mapping
NR PHY Replacement Strategies
New RAT: “New PHY” with Other Protocols

RAT with New PHY

3GPP Access      Non-3GPP Access

Treat the new RAT as a New 3GPP RAT
- Ex: New_RAT1, New_RAT2, ..., New_RATn depending upon the # of new RAT flavors
- Analogy: NTN RAT (Ex: "NR(LEO)", "NR(MEO)", "NR(GEO)", and "NR(OTHERSAT)")
- When NR L2 and L3 are used with NRAT L1, this approach would likely work well

Treat the New RAT as new Non-3GPP Access such as Wi-Fi
- Untrusted Non-3GPP Access (Wireless)
- Trusted Non-3GPP Access (Wireless)
- Wireline (Non-3GPP) Access

NRAT: New Radio Access Technology
NRAT Strategies

NRAT Offload (like Wi-Fi Offload) [No coordination between 5G and NRAT]

Untrusted Non-3GPP Access

Trusted 3GPP Access

Access Traffic Steering, Switching, and Splitting (ATSSS)

Dual Connectivity (NRAT + NR)

Standalone NRAT with 5GC (multiple flavors)
NRAT as Untrusted Non-3GPP Access

Single RAT access or simultaneous 3GPP access and untrusted NRAT access
All L1, L2, and L3 belong to NRAT; no reuse of NR L1, L2, and L3
The 5GC is used for UE-AMF signaling as well as UE-UPF traffic exchange

Acknowledgment. This diagram has been borrowed from 3GPP specifications.
NRAT as Trusted Non-3GPP Access

Single RAT access or simultaneous 3GPP access and trusted NRAT access
All L1, L2, and L3 belong to NRAT; no reuse of NR L1, L2, and L3
The 5GC is used for UE-AMF signaling as well as UE-UPF traffic exchange

Acknowledgment. This diagram has been borrowed from 3GPP specifications.
Single RAT access or simultaneous 3GPP access and untrusted or trusted NRAT access
All L1, L2, and L3 belong to NRAT; no reuse of NR L1, L2, and L3
The 5GC is used for UE-AMF signaling as well as UE-UPF traffic exchange
More control over the transport of user traffic by the network compared to a non-ATSS scenario

Acknowledgment. This diagram has been borrowed from 3GPP specifications.
Dual Connectivity (NRAT + NR)

Dual Connectivity:
Simultaneous connection of a UE to two Base Stations with independent schedulers

One RAT can provide the Master Node and the other RAT can provide the Secondary Node. Any RAT (i.e., NRAT or NR) can provide a Master Node. One RAT or both RATs can be used for data transfer.
The NRAT works without any assistance from the NR RAT. The NRAT BS needs to support Next Generation Application Protocol (NGAP) toward the 5GC.
Impact of PHY on RAN
Integrated gNB with Separate BBU and RU

Widely used in LTE and 5G deployments

Significant changes to the BBU due to new NRAT PHY when NR L2 and L3 are reused
Disaggregated gNB (Functional Split 2)

One of the emerging trends for 5G RAN deployments
Significant changes to the gNB-DU when NR L2 and L3 are reused
Some changes in the gNB-CU when NR L2 and L3 are reused
Emerging trend for 5G RAN deployments

Developed by the O-RAN Alliance

Openness and Intelligence for RAN

Significant impact of PHY changes on the O-RAN-based 5G RAN

Acknowledgment. This diagram has been borrowed from O-RAN specifications.

[Reference: O-RAN Alliance, O-RAN Architecture Description 5.0 - July 2021]
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Impact of PHY on 5GC
The 5GC does need to be modified to support NRAT but the extent of changes is much smaller compared to RAN and UE changes.

Impact of New RAT on 5GC

- **Charging**
- **Network Slicing and QoS**
- **A. PLMN and Access Network Selection**
- **B. New RAT Access:** Pseudo-3GPP access or Non-3GPP access
- **Simultaneous 3GPP and NRAT Access?**
- **Registration and Connection Management**
Impact of PHY on UE
The UE undergoes significant changes with more changes needed for complex and high-performance NRAT strategies

Implementation of NRAT PHY

Implementation of NRAT L2 and L3 or modification of NR L2 and L3

Access Network selection using UE policies (provisioned and configured)

RAT measurements for PDU Session transfer

Access Stratum and Non-Access Stratum signaling exchange

User Traffic Exchange via one or more RATs
Key Takeaways

Different strategies are feasible to support new PHY layer in 5G.

A new PHY can be supported by new L2 and L3 or modified NR L2 and L3.

The new PHY layer can be used in a new RAT that can be implemented as (pseudo-) 3GPP access or untrusted/trusted non-3GPP access.

Significant changes to an integrated gNB, disaggregated gNB, or O-RAN-based gNB are needed to support a new PHY layer.

The 5GC also needs some changes although the extent of 5GC changes is much smaller compared to the RAN and UE changes.
References


Thank You!

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